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(54) METHOD FOR FORMING AMORPHOUS ALLOY MEMBER

(57) A method for forming an amorphous alloy member. In the method, within a temperature range from the liquidus temperature to the glass transition temperature in the solidification process of a molten amorphous alloy, low-pressure precision forming is carried out for the amorphous alloy. The method makes use of a smooth, free surface formed after the molten alloy solidifies, good deformation property and low shrinkage coefficient during solidification, to obtain an amorphous alloy member that has high dimensional precision, high surface smoothness and a compact structure without defects such as shrinkage cavities and shrinkage porosity. The method features a short technological process, high production efficiency, and reduced costs.

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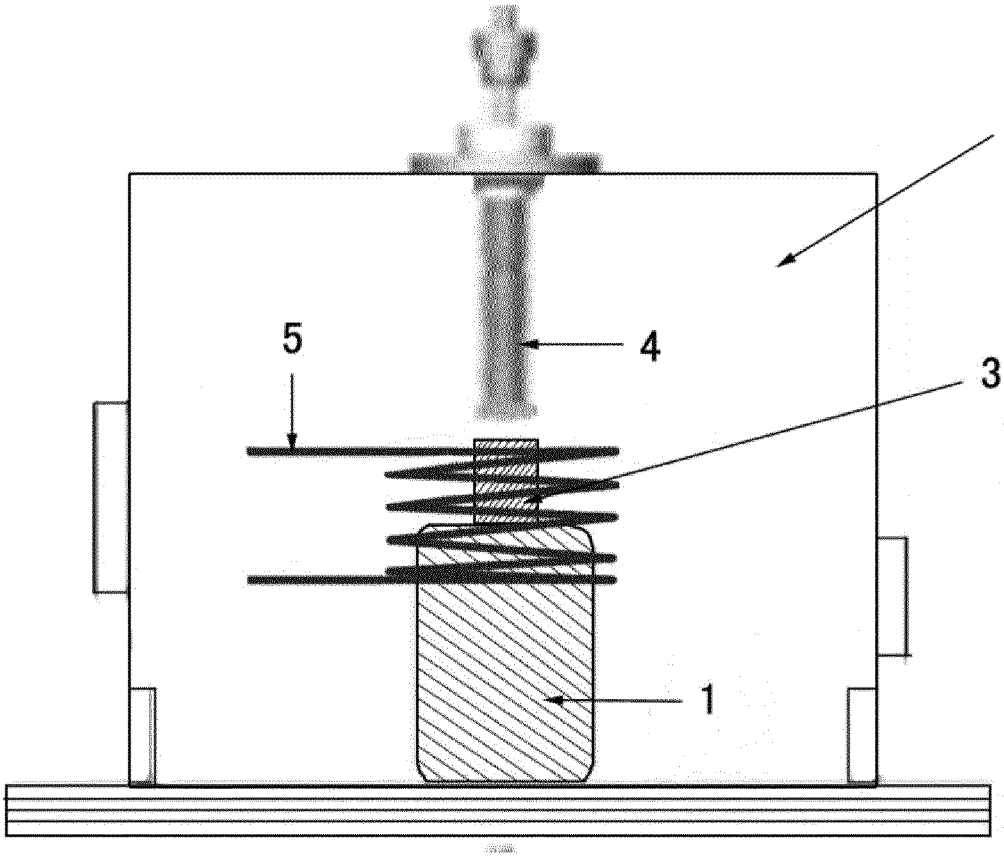

FIG. 1

Description

[0001] The invention relates to a method for forming an amorphous alloy part.

[0002] Amorphous alloy composite, due to its unique structural features, features special characteristics including high intensity, high abrasion resistance, high corrosion resistance and unique deformation performance etc. Therefore, amorphous alloy composite has wide applications in fields such as aerospace materials, defense industry, and consumer electronics. Typically, there are two methods for preparing an amorphous alloy part: vacuum die-casting technique and alloy-shaping technique at supercooled liquid region. The vacuum die-casing technique fills the mold cavity with the alloy melt under certain pressure, then the alloy melt is cooled, and mold filling and alloy shaping are realized at the liquidus temperature. By using this method, parts having complex structures are quickly and efficiently prepared. However, irregular pores having different sizes tend to form on the surface of the product and in the core of the product. Meanwhile, perfect vacuum condition is difficult to realize, and quality of the product cannot be ensured. The alloy-shaping technique heats the amorphous alloy to a temperature between the glass transition temperature (Tg) and the initial crystallization temperature (Tx), and the alloy is shaped under certain pressure at a certain speed, which means, the shaping of the amorphous alloy is performed at a narrow temperature range. This method is complex and inefficient because amorphous base materials is required to be prepared first. The temperature and the shaping duration needs to be strictly controlled, or the products tend to crystallize, resulting in performance deterioration.

[0003] In view of the above-described problems, it is one objective of the invention to provide a method for forming an amorphous alloy part. By using the method, the amorphous alloy can be precisely shaped under low pressure at the solidification temperature of the amorphous alloy melt. The method is efficient and cost-saving; the technical process is short; and the quality of the resultant products is high.

[0004] To achieve the above objective, in accordance with one embodiment of the invention, the following technical solutions are adopted:

[0005] A method for forming an amorphous alloy part, comprises: placing a master alloy having certain components and weight on a melting platform; heating and melting the master alloy under vacuum to yield an alloy melt; stopping heating and allowing the alloy melt to naturally cool to a temperature between a glass transition temperature and a liquidus temperature thereof; and press-forming using a forming mold and quickly cooling the alloy melt, to form the amorphous alloy part.

[0006] In a class of this embodiment, the master alloy is capable of forming amorphous alloy when the master alloy has uniform composition. The master alloy is prepared by smelting or casting. The master alloy is in a regular shape of rod, plate, flake, or sphere. A weight of the master alloy is determined by a shape and a size of the amorphous alloy part.

[0007] In a class of this embodiment, the vacuum is at a pressure of between 1×10^{-6} and 1×10^{-1} Pa.

[0008] In a class of this embodiment, the material of the melting platform does not react with the master alloy and has no influence on melting and solidification of the master alloy.

[0009] In a class of this embodiment, a heating mode of the master alloy is electric arc heating, induction heating, resistance heating, laser heating, plasma heating, infrared heating, or microwave heating.

[0010] In a class of this embodiment, in 4), a cooling rate is between 10^{-2} and 10^{2} K/min. The cooling of the alloy melt is performed via a cooling mold or a cooling melting platform to yield an amorphous structure.

[0011] The method for forming the amorphous alloy part is applicable to preparations of all amorphous alloy parts comprising Zirconium-based amorphous alloy, Titanium-based amorphous alloy, Iron-based amorphous alloy, Nickel-based amorphous alloy, Aluminum-based amorphous alloy, Magnesium-based amorphous alloy, Palladium-based amorphous alloy, Silver-based amorphous alloy, Gold-based amorphous alloy, Hafnium-based amorphous alloy, Calcium-based amorphous alloy, Platinum-based amorphous alloy, Copper-based amorphous alloy, Cobalt-based amorphous alloy, and rare-earth based amorphous alloy.

[0012] Advantages of the method for forming an amorphous alloy part according to embodiments of the invention are summarized as follows:

1. Following the melting of the master alloy, the amorphous alloy is precisely formed under low pressure at the solidification temperature range of the amorphous alloy melt, that is, between the liquidus temperature (Tl) and the glass transition temperature (Tg). Within the temperature range, the formed alloy melt has smooth surface, good deformation property, and small solidification and contraction coefficient. The prepared amorphous alloy part has accurate size, smooth surface, compact structure, and free of shrinkage hole.

2. The method is efficient and cost-saving, has short technical process, and the prepared products have high quality.

FIG. 1 is a schematic diagram of an apparatus used in a method for forming an amorphous alloy part in accordance with one embodiment of the invention;

In FIG. 1, the following reference numbers are used: 1. Melting platform; 2. Vacuum chamber; 3. Master alloy; 4. Mold; and 5. Heating unit.

FIG. 2 is a Titanium-based amorphous alloy part in Example 1;

FIG. 3 is a Zirconium-based amorphous alloy part in Example 2; and

FIG. 4 is an X-ray diffraction diagram of an amorphous alloy part.

[0013] For further illustrating the invention, experiments detailing a method for forming an amorphous alloy part are described below. It should be noted that the following examples are intended to describe and not to limit the invention.

[0014] As shown in FIG. 1, a master alloy 3 having certain components and certain weight is placed on a melting platform 1. Air in the vacuum chamber 2 is exhausted, and the master alloy 3 is heated and melted using a heating unit 5 under vacuum to yield an alloy melt. Heating is stopped and the alloy melt is naturally cooled to a temperature between a glass transition temperature (Tg) and a liquidus temperature (Tl). The alloy melt is pressed using the mold 4 and cooled, to form the amorphous alloy part.

Example 1

[0015] The shaping process of amorphous alloy part in the example is as follows:

1. Composition of the master alloy (atomic percentage): 32.8% of Titanium, 30.2% of Zirconium, 5.3% of Nickel, 9% of Copper, and 22.7% of Beryllium.

2. Melting the master alloy: the material of the master alloy is prepared and is placed in a crucible. Air is exhausted to form a vacuum at a pressure of between 5×10^{-3} and 5×10^{-1} Pa (or inert gas is filled in). The master alloy with uniform composition are prepared by induction melting or electric arc melting. The master alloy is casted to form regular master alloy ingot (in the shape of rod, plate, or flake, etc.)

3. Cutting the master alloy: the casted master alloy ingot is cut using cutting equipment according to the weight of required amorphous alloy part.

4. Shaping and processing amorphous alloy part: the cut master alloy is placed on a melting platform. Air in the vacuum chamber is exhausted to form a vacuum at a pressure of between 1×10^{-3} and 1×10^{-1} Pa (or inert gas is filled in). The master alloy is heated and melted by induction heating (or other heating modes such as electric arc heating, laser heating, etc.) to yield an alloy melt. Heating is stopped and the alloy melt is freely cooled to a temperature which is 20°C higher than the melting temperature (in the temperature range between a glass transition temperature (Tg) and a liquidus temperature (Tl) of the amorphous alloy). The alloy melt is pressed using the mold until the mold cannot further move to contact the melting platform (or a specialized shaping platform in which the alloy melt is poured following the melting). Meanwhile, the alloy melt is quickly cooled to form the amorphous alloy part as shown in FIG. 2; in the example, the quick cooling is performed using a cooling melting platform, and the cooling rate is 10^{-1} K/min.

Example 2

[0016] The example follows a basic process in Example 1, except that composition of the master alloy (atomic percentage) is: 54.73% of Zirconium, 29.75% of Copper, 4.97% of Nickel, 9.95% of Aluminum, 0.1 % of Silver, and 0.5% of Yttrium. The amorphous alloy part prepared in the example is shown in FIG. 3.

[0017] As shown in FIGS. 2-3, the amorphous alloy part prepared by the method has smooth surface and accurate size. Analyzed from the scanning electron microscope, the amorphous alloy part has compact structure and no shrinkage hole (as shown in FIG. 4).

[0018] The alloy used in the embodiments of the invention can be any amorphous alloy, such as Titanium-based amorphous alloy, Zirconium-based amorphous alloy, Iron-based amorphous alloy, Nickel-based amorphous alloy, Magnesium-based amorphous alloy, Palladium-based amorphous alloy, Silver-based amorphous alloy, Hafnium-based amorphous alloy, Platinum-based amorphous alloy, or other amorphous alloy component of other system.

Claims

1. A method for forming an amorphous alloy part, the method comprising: placing a master alloy having certain components and weight on a melting platform; heating and melting the master alloy under vacuum to yield an alloy melt; stopping heating and allowing the alloy melt to naturally cool to a temperature between a glass transition temperature and a liquidus temperature thereof; and press-forming using a forming mold and quickly cooling the alloy melt, to form the amorphous alloy part.

2. The method of claim 1, **characterized in that** the master alloy is capable of forming amorphous alloy when the master alloy has uniform composition.

3. The method of claim 1 or 2, **characterized in that** the master alloy is prepared by smelting or casting; the master alloy is in a shape of rod, plate, flake, or sphere; and a weight of the master alloy is determined by a shape and a size of the amorphous alloy part.

4. The method of claim 1, **characterized in that** the vacuum is a pressure of between 1×10-6 and 1×10^{-1} Pa.

5. The method of claim 1, **characterized in that** the melting platform does not react with the master alloy and has no influence on melting and solidification of the master alloy.

6. The method of claim 1, **characterized in that** a heating mode of the master alloy is electric arc heating, induction heating, resistance heating, laser heating, plasma heating, infrared heating, or microwave heating.

7. The method of claim 1, **characterized in that,** a cooling rate of the alloy melt is between 10^{-2} and 10^{2} K/min; the quick cooling of the alloy melt is performed by a cooling mold or a cooling melting platform to yield an amorphous structure

8. The method of claim 1, **characterized in that** the method is applicable to all amorphous alloy systems.

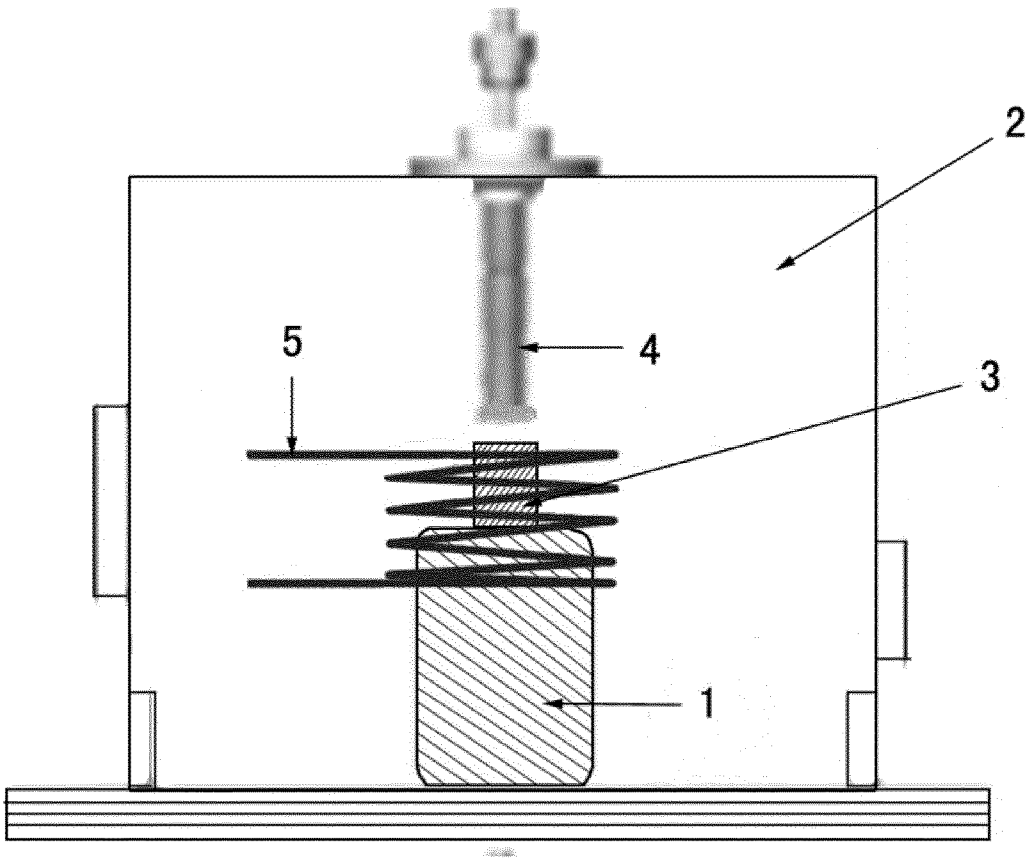

FIG. 1

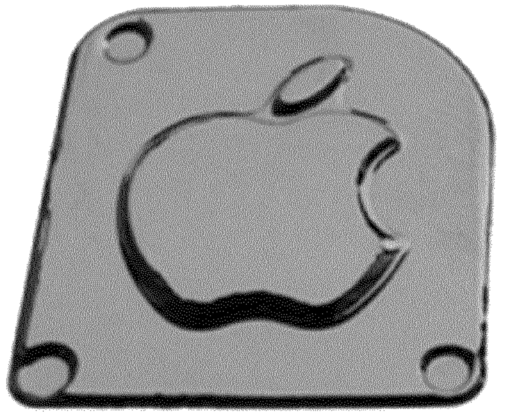

FIG. 2

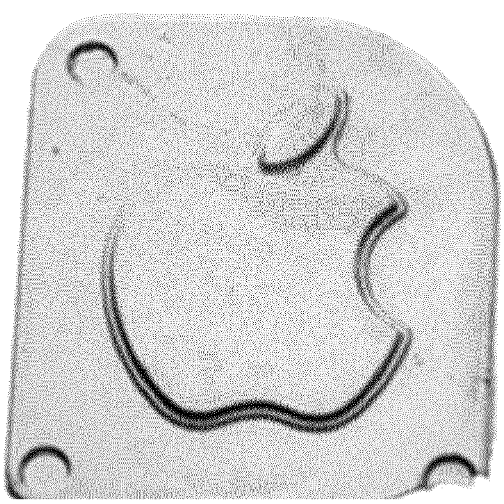

FIG. 3

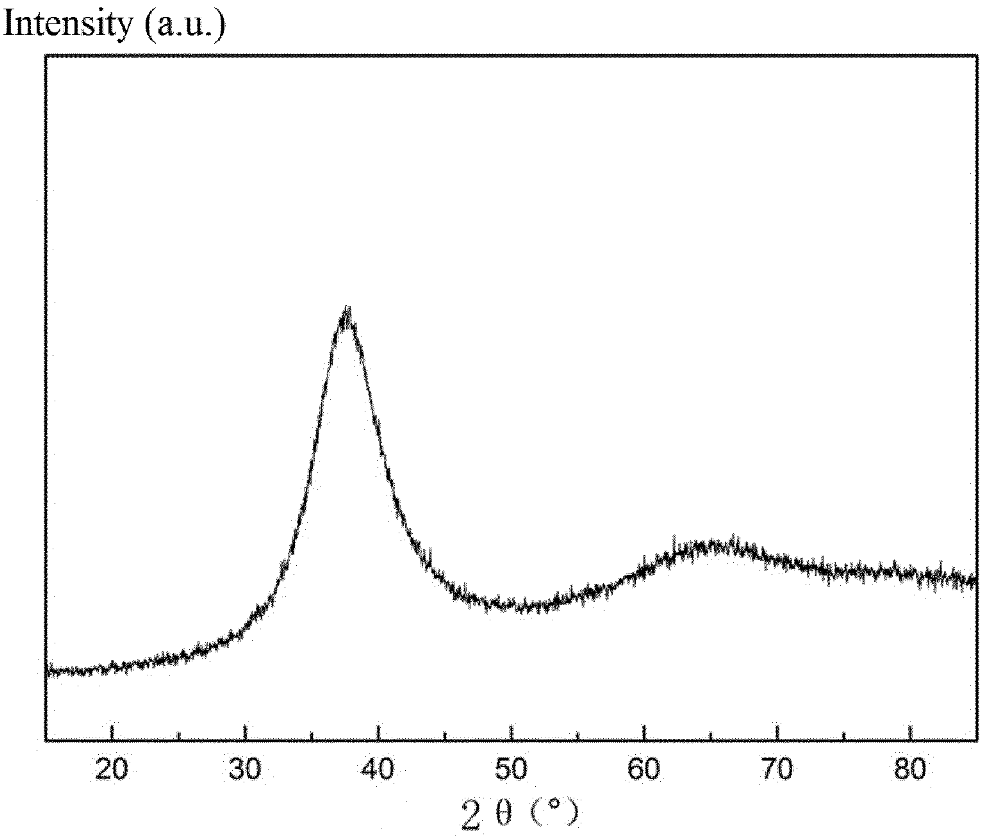

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2015/083961

A. CLASSIFICATION OF SUBJECT MATTER

C22C 45/00 (2006.01) i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C22C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNPAT, WPI, EPODOC, CNKI: cool+, temperature, heat+, melt+, vac+, amorphous, alloys, liquidus

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 102534433 A (BEIJING INSTITUTE OF TECHNOLOGY) 04 July 2012 (04.07.2012) description, paragraph [0032]	1-8
A	CN 102234746 A (INSTITUTE OF PHYSICS, CHINESE ACADEMY OF SCIENCES) 09 November 2011 (09.11.2011) the whole document	1-8
A	CN 102529192 A (BYD CO., LTD.) 04 July 2012 (04.07.2012) the whole document	1-8
A	CN 1438083 A (JIANGSU UNIVERSITY) 27 August 2003 (27.08.2003) the whole document	1-8
A	CN 1095764 A (INSTITUTE OF METAL, CHINESE ACADEMY OF SCIENCES) 30 November 1994 (30.11.1994) the whole document	1-8
A	US 2008081213 A1 (FUJI XEROX CO., LTD. ET AL.) 03 April 2008 (03.04.2008) the whole document	1-8

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&"document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
21 September 2015	09 October 2015

Name and mailing address of the ISA	Authorized officer
State Intellectual Property Office of the P. R. China No. 6, Xitucheng Road, Jimenqiao Haidian District, Beijing 100088, China Facsimile No. (86-10) 62019451	ZHANG, Yongfeng Telephone No. (86-10) 62413093

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2015/083961

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
CN 102534433 A	04 July 2012	None	
CN 102234746 A	09 November 2011	None	
CN 102529192 A	04 July 2012	None	
CN 1438083 A	27 August 2003	None	
CN 1095764 A	30 November 1994	None	
US 2008081213 A1	03 April 2008	EP 1918409 A2	07 May 2008
		CN 101152822 A	02 April 2008
		JP 2008081819 A	10 April 2008

Form PCT/ISA /210 (patent family annex) (July 2009)